Materials
Rec'd 12-23-80
R.P. #81

PREDICTING MOISTURE-INDUCED DAMAGE TO ASPHALTIC CONCRETE

PROGRESS REPORT ON FIELD EVALUATION PHASE OF NCHRP PROJECT 4-8(3)/1

Prepared for Presentation at
Sixty-Sixth Annual Meeting
American Association of State Highway and Transportation Officials
Hotel Sahara
Las Vegas, Nevada
November 16-19, 1980
Materials Subcommittee Session

University of Idaho
R.P. Lottman
Moscow, Idaho 83843

Acknowledgment

This work was sponsored by the American Association of State Highway and Transportation Officials, in cooperation with the Federal Highway Administration, and was conducted in the National Cooperative Highway Research Program which is administered by the Transportation Research Board of the National Research Council.

TABLE OF CONTENTS

SUMMARY

The research reported herein is being performed under NCHRP Project 4-8(3) by seven highway agencies: Arizona Department of Transportation, Colorado Division of Highways, Region 10 of the Federal Highway Administration, Georgia Department of Transportation, Idaho Transportation Department, Montana Division of Highways, and Virginia Highway and Transportation Research Council.

The primary research program (Phase I) was conducted by the University of Idaho, with assistance by Battelle-Northwest and the University of Washington. The study produced a tentative laboratory test method for predicting moisture damage in dense-graded asphaltic concrete mixtures and is reported in NCHRP Report 192 "Predicting Moisture-Induced Damage to Asphaltic Concrete," and in Appendix A of the Interim Report, February 1979, for the current 4-8(3) field evaluation phase. The proposed test method includes the following steps. Laboratory specimens are fabricated from the asphalt and aggregate materials to be used in the intended pavement mixture, and are compacted to duplicate the expected permeable voids of the pavement mixture. Short-term moisture damage (for pavement life up to 24 months) is predicted on the basis of the mechanical properties of specimens that are vacuum saturated and compared to dry specimens. Long-term moisture damage (for pavement life up to and through 60 months) is predicted on the basis of the mechanical properties of specimens that are vacuum saturated and subjected to accelerated conditioning (freeze-plus-warm-water soak) and compared to dry specimens. Mechanical properties used are tensile strength and resilient modulus (diametral loading). The comparison of mechanical properties is expressed quantitatively as a ratio. Ratios less than 1.00 denote moisture damage; the damage increases as the ratio becomes smaller.

The foregoing test method is now being evaluated in the current (Phase II) study, the field evaluation phase of NCHRP Project 4-8(3). Eight test sections from new asphaltic concrete pavements have been designated by the seven highway agencies for laboratory testing and periodic sampling. The aggregates used in most of the pavement test sections are considered to have some moisture susceptibility, based on past experience. The pavement sections are in locations that have a wide range of freezing index and precipitation.

Approximately 60 months of moisture damage data accumulated from periodic sampling of the test sections are being collected, analyzed, and compared to the laboratory-predicted moisture damage based on the short-term and long-term ratios of laboratory specimens and initial cores. Visual stripping and pavement performance are also being compared.

This field evaluation report represents the first 48 months of pavement data obtained from the cores compared to laboratory predictions. The following is a summary of the findings to date.

In general, the short-term moisture damage predictions provided high ratios, around 0.80, implying that the pavements' asphaltic mixtures would not experience an initial, rapid loss of mechanical properties because of moisture. However, the long-term moisture damage prediction ratios have a larger range, from 0 (complete disintegration) to 0.80+ (generally resistant to moisture), depending on the pavement test section. This prediction range provides a strong basis for evaluation of the test system--a good "test of the test".

The highway agencies have been obtaining sets of cores from their pavement test section every few months for the purpose of quantifying pavement damage and comparing it to the predicted damage. The cores have been dried, vacuum saturated and tested in the laboratory and the mechanical property ratios have been calculated. Early pavement life, up to about 24 months, shows increased ratios in most cases of the periodic cores -- an interesting development. Instead of an expected gradual deterioration trend of mechanical properties, pavement tensile strength and stiffness (modulus) increased more rapidly when the specimens were subjected to saturation than they were in the dry state. This may be due to moisture stiffening of the asphalt mastic in the mixes. Later the periodic core ratios started to decrease and the trend appears to be continuing for most of those pavements predicted to have long-term moisture damage. The periodic core ratios at 48 months remain above the predicted long-term ratios. Most of the periodic core ratio decreases seemed to be confirmed after the second winter. Some of the cores are now showing stripping; cores for two test sections are disintegrating because of extensive stripping.

Not enough data have been accumulated to determine the final accuracy of the moisture damage predictions. Final periodic core drilling and tests will be either in the fall 1980 or spring 1981, depending on the age of the pavement. Additional cores will be tested to determine immediate saturated ratios in order to provide a closer bracketing of more accurate pavement moisture damage at time of core drilling.

The effects of environment and moisture have "settled in" the pavements and, for the pavement test sections that are predicted to have moderate to severe moisture damage, the increasing trend of rate of moisture damage seems to have begun for most of the pavements.

INTRODUCTION

The phenomenon of adhesion between asphalt cement and aggregates in an asphaltic concrete is very complex and not clearly understood at this time. The loss of bond (stripping) because of the presence of moisture between the asphalt and the aggregate is a problem in many areas of the country and is severe from the standpoint of highway pavement performance in some instances. Although the problem is influenced by many factors, such as asphalt characteristics, aggregate properties, mix design, construction procedures, environmental conditions, and traffic, the vast amount of field experience indicates that the presence of moisture in combination with the other factors is most critical with regard to the phenomenon of adhesion between the asphalt cement and the aggregates.

Ultimately, identification must be made of the aggregate properties and the asphalt cement characteristics that affect adhesion. This knowledge is basic to the development of techniques that are needed for optimizing the choice of materials or for specifying appropriate corrective measures where loss of bond is likely to be a problem. However, the accomplishment of these ultimate objectives requires fundamental studies that are time consuming and necessitate the development of test methods for correlating the findings with field performance.

Research conducted under NCHRP Project 4-8(3), "Predicting Moisture-Induced Damage to Asphaltic Concrete," has provided both a tentative test method for predicting the susceptibility of asphaltic concrete mixtures to moisture damage and a general plan for a comprehensive field evaluation of the method. The essential findings from Phase I are included in NCHRP

Report 192, "Predicting Moisture-Induced Damage to Asphaltic Concrete".

The objective of the field evaluation study (Phase II) is to provide verifications of the test method tentatively proposed in Phase I. The study is scheduled for 6.5 years, including 5 years of field data evaluation for most of the pavement test sections.

In order to develop a more "real life" situation and, at the same time, provide a wider range of experience with the test method, cooperative arrangements have been made in the six state highway agencies and Region 10 of the Federal Highway Administration to perform the field and laboratory testing using test pavements constructed in 1975 and 1976. Coordination, data analysis and correlation, and writing of reports is the responsibility of the University of Idaho.

Table 1 contains information on the pavement test section constructed by the participating highway agencies. Location, pavement thickness, and general materials description are given in the table.

Predictions of Moisture Damage

The test method developed in NCHRP Project 4-8(3) uses laboratory-fabricated specimens made with asphalts and aggregates similar to that used in the pavement test sections. The specimens contain permeable voids equivalent to those in the pavement sections. Moisture damage predictions are evaluated by comparing lab-specimen and initial core ratios with periodic core ratios.

Also evaluated are the differences of moisture damage prediction due to the following conditions:

TABLE 1
PAVEMENT TEST SECTION LOCATIONS AND INFORMATION

STATE/ AGENCY	ROUTE	YEAR PAVED AND INITIAL CORING DATE	PAVEMENT LAYER THICKNESSES	TEST LAYER: PERIODIC CORES AND LABORATORY MIX MATCHING	TEST LAYER: MIX AGGREGATES AND ASPHALT
Arizona	Green Valley, I-19	1975 (Oct.)	7.5 in. asph. conc. 10 in selected subbase	Lower 2.5 in. of asph. conc.	Santa Cruz river gravels asphalt cement (no additives)
Colorado	Arapahoe Rd., S.R. 88	1976 (Jun.)	1.5 in. asph. conc. wearing 2 in. asph. conc. leveling 7 in. asph. conc. base (3/4 in max. agg. size)	Lower 2.5 in. of asph. conc. base	Morrison cr. stone - coarse agg. Platte River (Littleton) - fine agg. asphalt cement (no additives)
FHWA Region 10	West Entrance Crager Lake N.P.	1975 (Nov.)	2 in. asph. conc. 10 in. cr. stone base	2 in. of asph. conc.	Pole Creek stockpile, Klamath County, w/14% blend sand asphalt cement (no additives)
Georgia	Walton County, U.S. 78	1977 (Mar)	1.5 in. asph. conc. wearing 2 in. asph. conc. leveling 7 in. asph. conc. base (3/4 in. max agg. size)	Lower 2.5 in. of asph. conc. base	granite gneiss asphalt cement w/.5% additive all layers
Georgia	Walton County, U.S. 78	1977 (Mar)	1.5 in. asph. conc. wearing 2 in. asph. conc. leveling 7 in. asph. conc. base (3/4-in. max agg. size)	Lower 2.5 in. of asph. conc. base	granite gneiss asphalt cement w/.5% additive in wearing and leveling and top 3 in. of asph. conc. base only. Lower 4 in. of base without additive.
Idaho	Whitebird, US 95	1975 (Nov.)	3.6 in. asph. conc. 8.4 in. cr. stone base	Lower 2.5 in. of asph. conc.	Salmon River gravels asphalt cement mix additive: 1% hydrated lime
Montana	Deer Lodge Pass South, I-15	1976(Jul.)	4.8 in. asph. conc. 16.8 in. cr. stone base	Lower 2.5 in. of asph. conc.	bench gravels asphalt cement (no additives)
Virginia	Greenwood Dr. Portsmouth I-264	1976 (May)	1.5 in. asph. conc. wearing 5.5 in. asph. conc. base (1 in. max size) 6 in. compacted agg.-sand 6 in. cement stabil. sub-grade	Lower 2.5 in. of asph. conc. base	granites - coarse agg. natural sand asphalt cement (no additives)

Note: 1 in. = 2.54 cm

1. Initially drilled cores (zero pavement age) vs. laboratory-fabricated specimens.
2. Laboratory-fabricated specimens at initially drilled core voids vs. laboratory-fabricated specimens at reduced voids (when feasible).
3. Several storage time exposures at room temperature for laboratory-fabricated specimens and initially drilled cores.

The proposed test method for predicting moisture damage for a given pavement mixture requires three sets of 4 compacted specimens each for testing and evaluation. One set remains dry; the second set is vacuum saturated; the third set is vacuum saturated and then subjected to an accelerated conditioning consisting of a freeze followed by a warm-water soak. Moisture damage predictions are based on ratios of average diametral tensile (splitting) strength and average resilient modulus for the vacuum-saturated sets and for the accelerated conditioned sets as related to the dry sets. A short-term moisture damage prediction for up to 2 years of pavement life is based on the ratios of the mechanical properties for vacuum-saturated vs. dry laboratory specimens. A long-term prediction for up to 5 years or more is based on the ratios of mechanical properties for accelerated conditioned vs. dry specimens.

The accelerated conditioning used in the test method determines the magnitude of moisture damage predicted, and this is an important consideration in this study. Results from NCHRP Project 4-8(3) (Phase I) showed that the accelerated conditioning most closely simulated the visual and mechanical properties of cores from moisture-damaged pavements. The accelerated conditioning induces internal tensile stress to the asphaltic concrete mixture structure through the development of internal water pressures in void fissures of the asphalt-fines matrix and at the asphalt-aggregate interfaces. The pressures are produced prior to and by ice formation, and by the differential thermal expansion stresses between water and asphaltic concrete mixture when the frozen, saturated mixture is subjected to the warm-water bath. In addition, the warm-water bath allows for emulsification to take place if the asphalt used in the mixture has this potential. Another result of the conditioning is that it seems to test the durability of the aggregates in the mixture, tending to break down the weaker, porous ones similar to that which has been observed with weak aggregates in asphaltic concrete pavement mixtures subjected to moisture.

Evaluation of Pavement Moisture Damage

In the evaluation procedure a group of 8 cores is obtained from the wheel path and another group of 8 cores is obtained from between the wheel path for each pavement test section at scheduled times of the year. The wheel path and between wheel path locations are evaluated as separate variables. The cores are desiccated to a dry condition in the laboratory. An 8-core group is separated into two 4-core sets. One set is tested dry, and the other set is vacuum saturated and tested for purposes of calculating the ratios at a given pavement age. The ratios are calculated from the average tensile strength (and modulus) obtained for a 4-core set. The standard deviation is also calculated. The field ratios are recorded periodically during the first 5 years of pavement life. In the present project, periodic evaluation was made every 4 months for the first 2 years and, thereafter, is being obtained every 6 months in the spring and in the fall.

The pavement moisture damage measurement is quantified by ratios obtained from field cores. The build-up of moisture and climatic effects will influence the ratios, and the ratios should decrease with increasing pavement age if the pavement mixture is moisture damage susceptible.

After the tensile strength or tensile splitting test is performed, the cores are split open and a visual, qualitative assessment of stripping is made. The periodic build-up of visual stripping is compared to the ratios.

Because the pavements absorb more moisture with age, it has been necessary to increase the times for the laboratory desiccation drying of the pavement cores prior to testing. Eight or more weeks are not unusual for the cores to reach constant weight. There is now some concern that the cores are "healing" during this drying time and giving ratios greater than the actual pavement moisture damage at the time of core drilling. Thus, additional ratios, called "immediate ratios", for the final scheduled core drilling must be calculated as well as the routine, after-desiccation ratios. In order to do this, an extra set of 4 cores from the wheel path and another 4 cores from between wheel paths must be drilled and subjected immediately to vacuum saturation and testing. The tensile strength (and modulus) obtained, divided by the desiccated dry strength (modulus) from the routine tested cores, provides the immediate ratios. The immediate and the routine after-desiccation ratios should bracket the actual pavement mixture's moisture damage at the time of core drilling.

The moisture damage evaluations based on the ratios of the periodic pavement cores are shown in Figures 1 through 8.

Comparison of Predictions and Actual Pavement Moisture Damage

In comparing periodic ratios of the pavement (field) cores to the predicted ratios, initial periodic pavement core ratios (over the first year or so of pavement age) should be approximately equal to the predicted vacuum-saturated ratios. As environmental and traffic effects build up in the pavement, the periodic pavement core ratios should decrease further and be approximately equal to the predicted accelerated conditioned ratios.

The matching of predictions to pavement moisture damage can be influenced by several factors, such as the wide, geographic location of the pavement test sections and the laboratory compaction methods used for the mixture specimens. Some of the influences are:

1. Traffic loading and volume.
2. Climate.
3. Build-up of adequate moisture.
4. Differences between laboratory specimens and pavement cores.
5. Aging of test specimens.
6. Reduced permeable voids of test specimens (and change of permeable voids of the pavement mixture with pavement age).
7. Test variability.

It is likely that a predictive methodology can be developed from a comparison of the relationship between these factors and the severity of moisture damage, although the primary matching consideration will be the predictions from tests of laboratory-fabricated specimens to actual 5-year pavement moisture damage regardless of the seven factors.

The predictive ratios and pavement moisture damage ratios are compared graphically in the Figures 1 through 8.

FINDINGS AND APPRAISAL

The findings represent approximately the first 4 years of pavement moisture damage evaluation. The fifth year data (with the addition of the immediate retained ratios) will be reported in the final report prepared under this project. Tensile (splitting) strength ratios are shown. Resilient modulus data show similar trends and will be shown in the final report.

Predictions

Moisture damage prediction ratios are plotted in Figures 1 through 8. In the figures, short-term prediction ratios are plotted vertically at the left of the pavement age scale (represent vacuum saturation), and long-term prediction ratios are plotted vertically on the right of the pavement age scale (represent vacuum saturation plus accelerated conditioning).

An explanation of the prediction ratio codes used these figures is based on the following examples:

C - 5	initial cores tested at 5-month storage time
L - 0	laboratory specimens tested at zero month storage time
LR - 2	laboratory specimens at reduced voids tested at 2-month storage time
SAT	vacuum saturated only
COND	vacuum saturated plus accelerated conditioned.

An examination of these figures shows that the short-term predictions give higher ratios than those calculated for the long-term predictions. This is to be expected. In some cases, the short-term predictions are greater

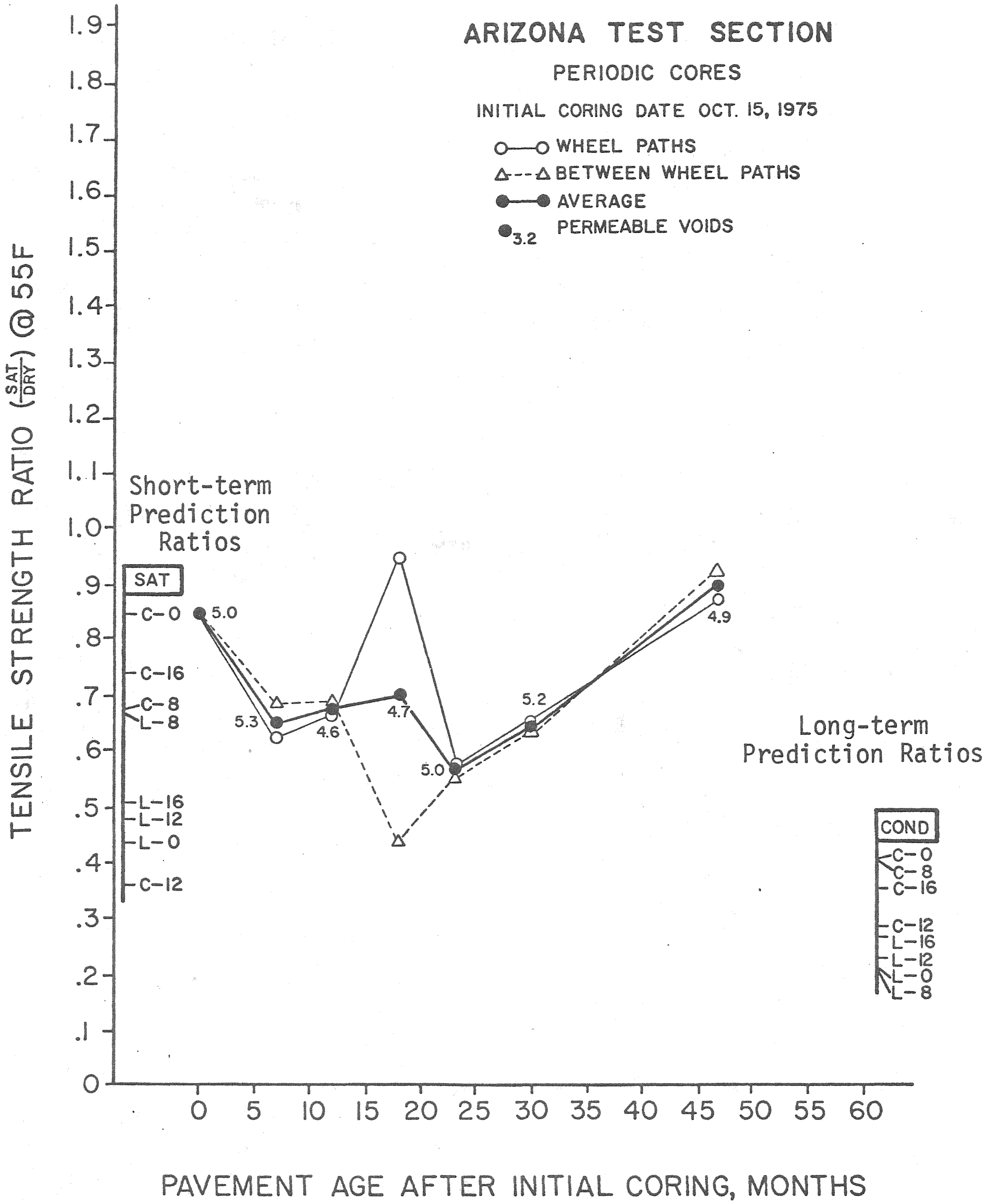

Figure 1. Tensile Strength Ratio of Field Cores vs. Pavement Age and Prediction Ratios for Arizona Test Section

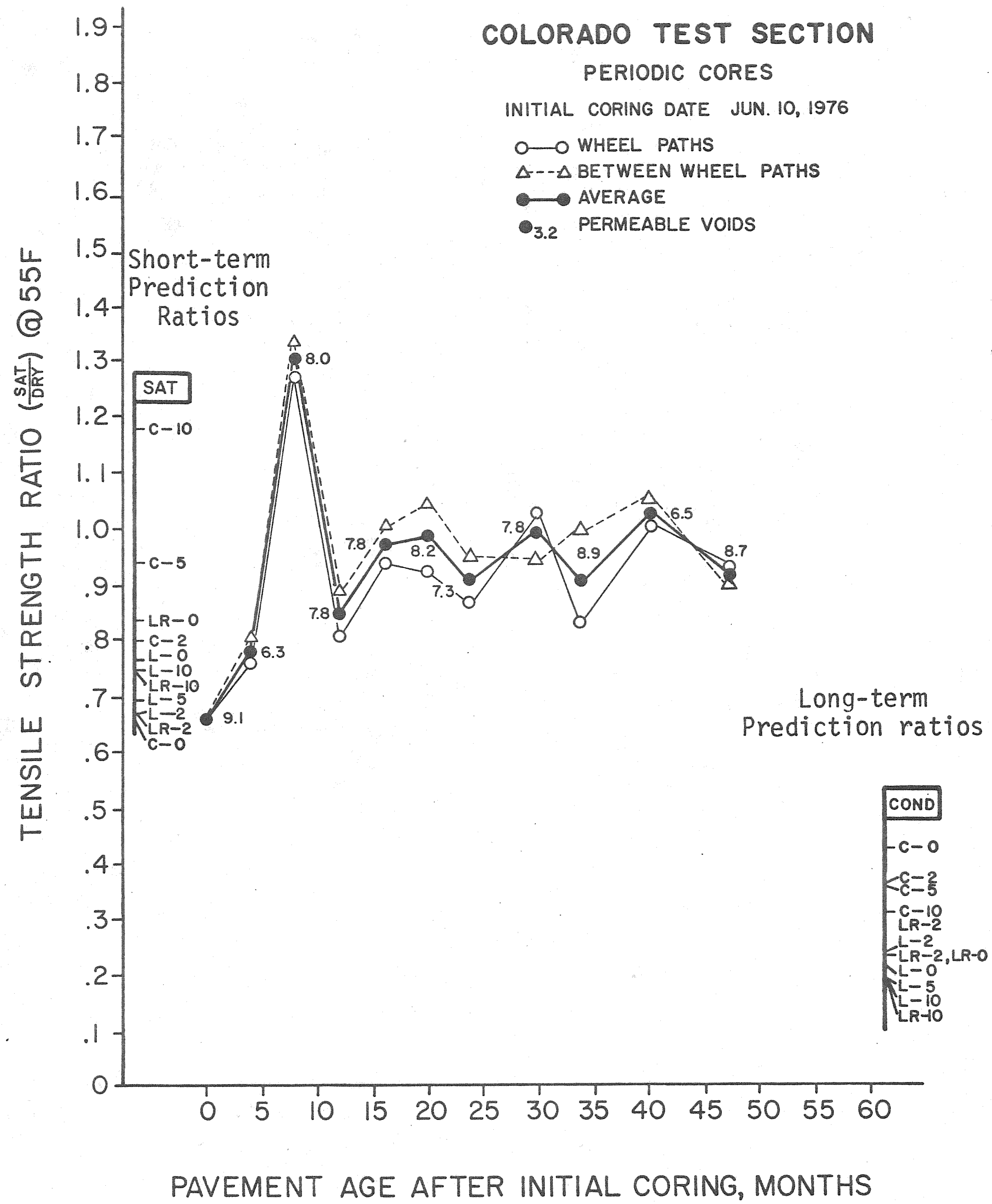

Figure 2. Tensile Strength Ratio of Field Cores vs. Pavement Age and Prediction Ratios for Colorado Test Section

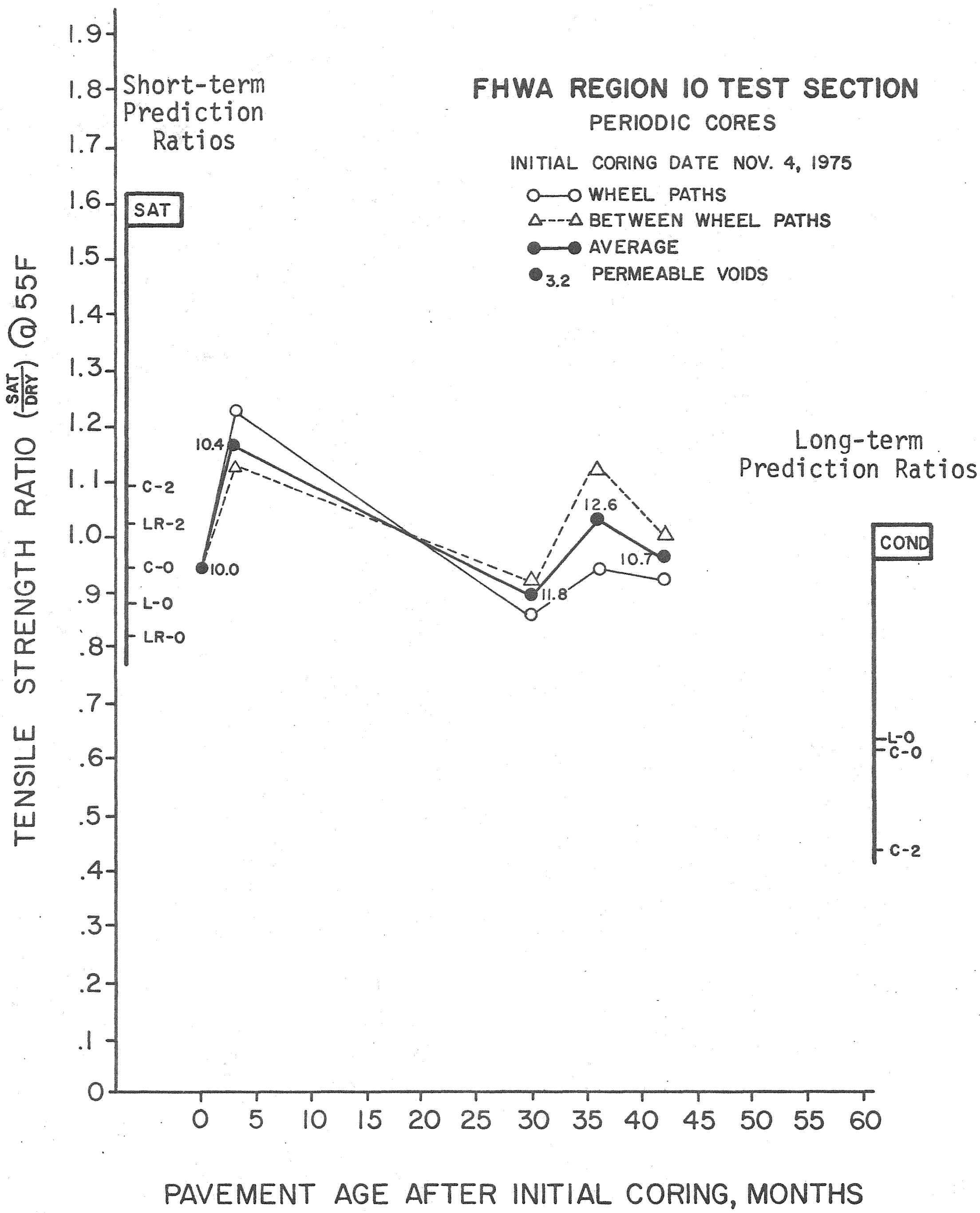

Figure 3. Tensile Strength Ratio of Field Cores vs. Pavement Age and Prediction Ratios for FHWA 10 Test Section

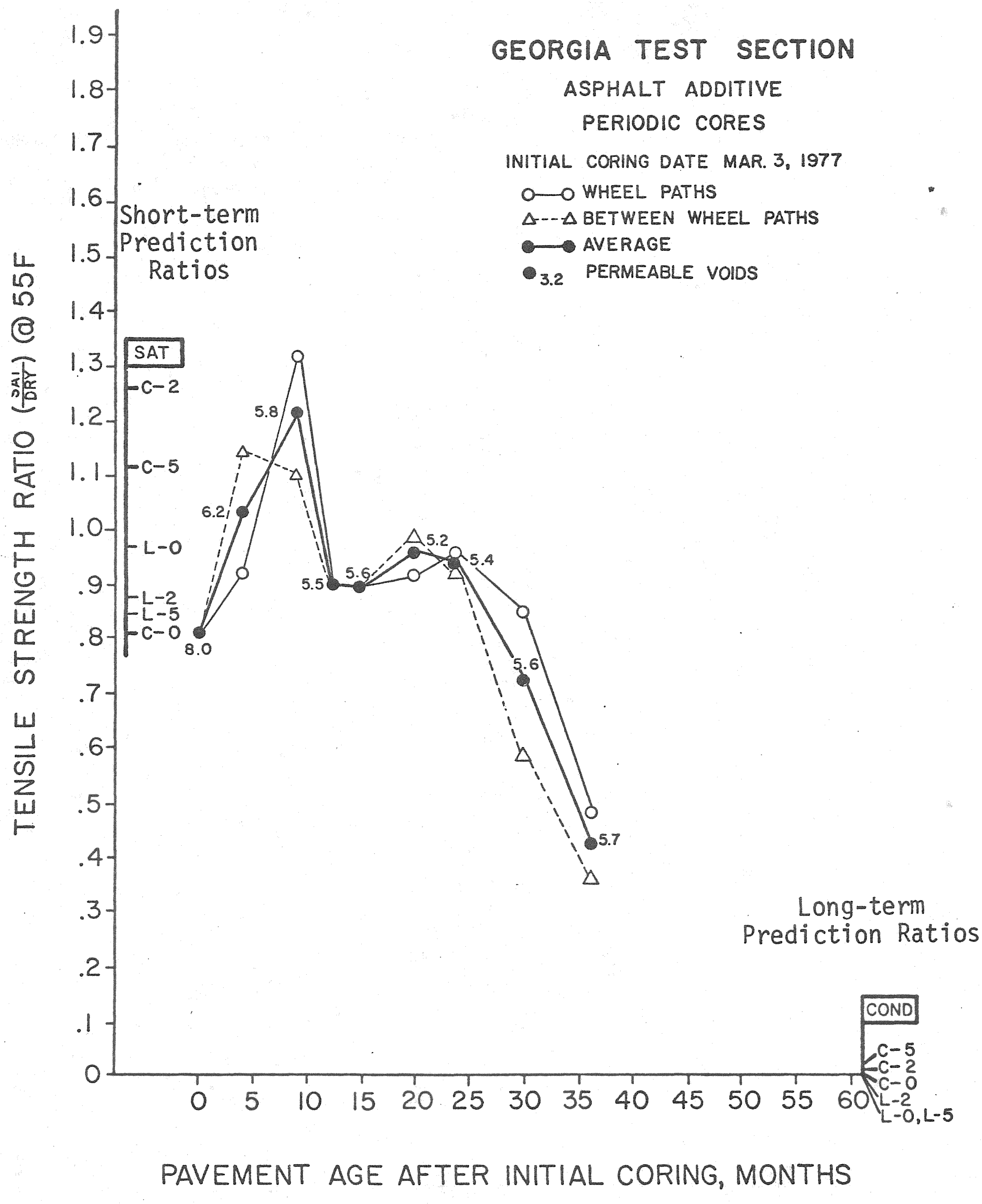

Figure 4. Tensile Strength Ratio of Field Cores vs. Pavement Age and Prediction Ratios for Georgia Additive Test Section

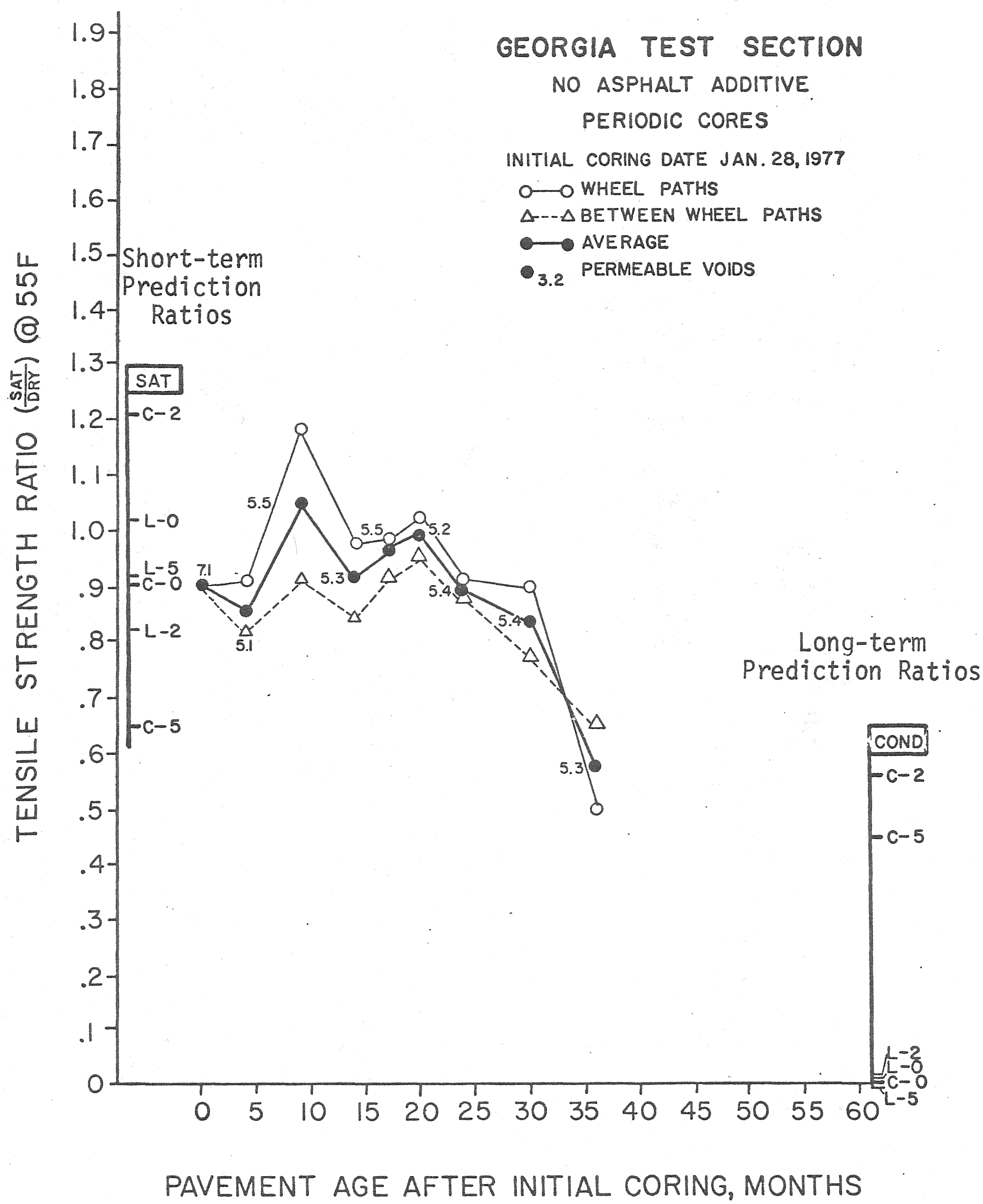

Figure 5. Tensile Strength Ratio of Field Cores vs. Pavement Age and Prediction Ratios for Georgia Nonadditive Test Section

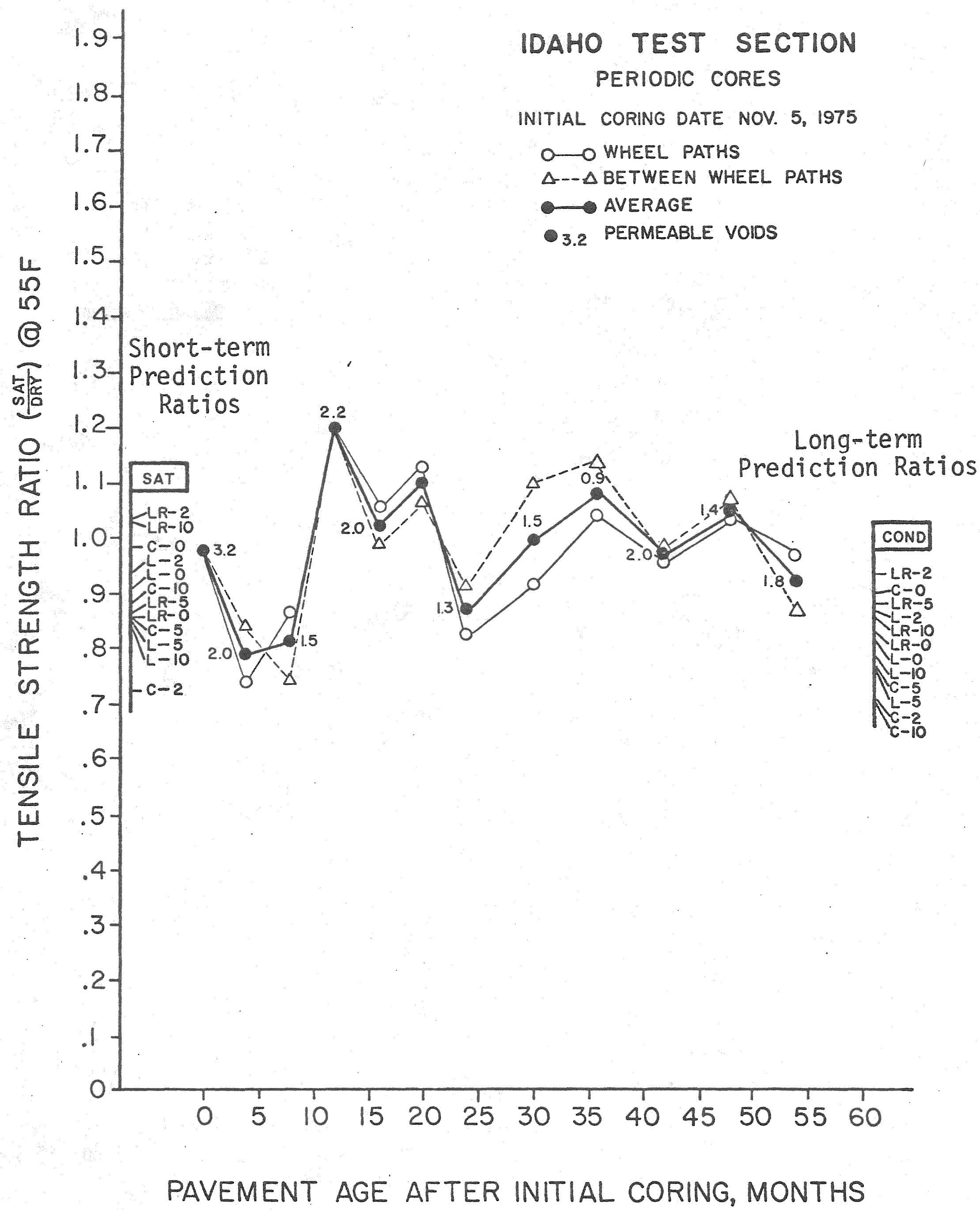

Figure 6. Tensile Strength Ratio of Field Cores vs. Pavement Age and Prediction Ratios for Idaho Test Section

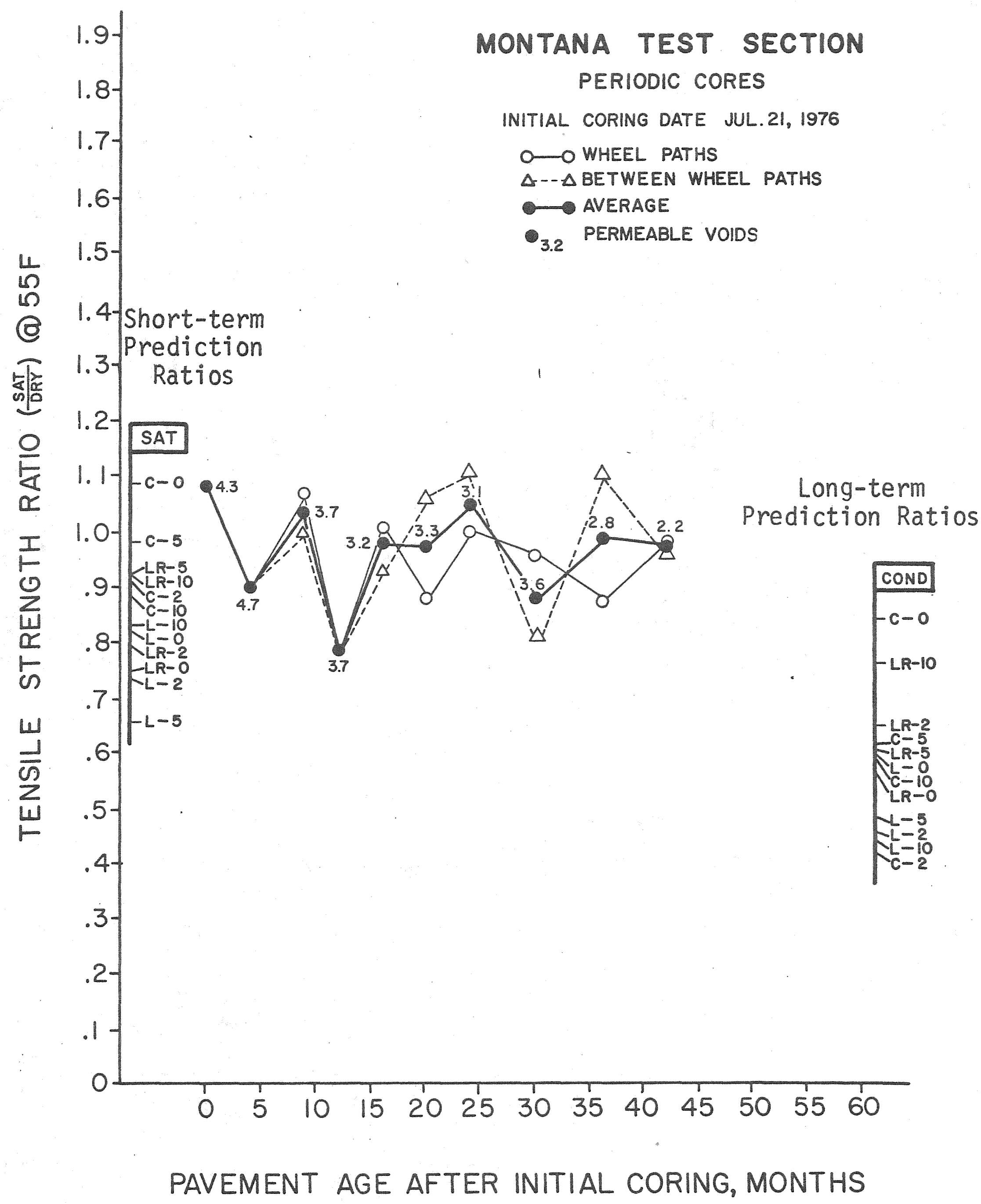

Figure 7. Tensile Strength Ratio of Field Cores vs. Pavement Age and Prediction Ratios for Montana Test Section

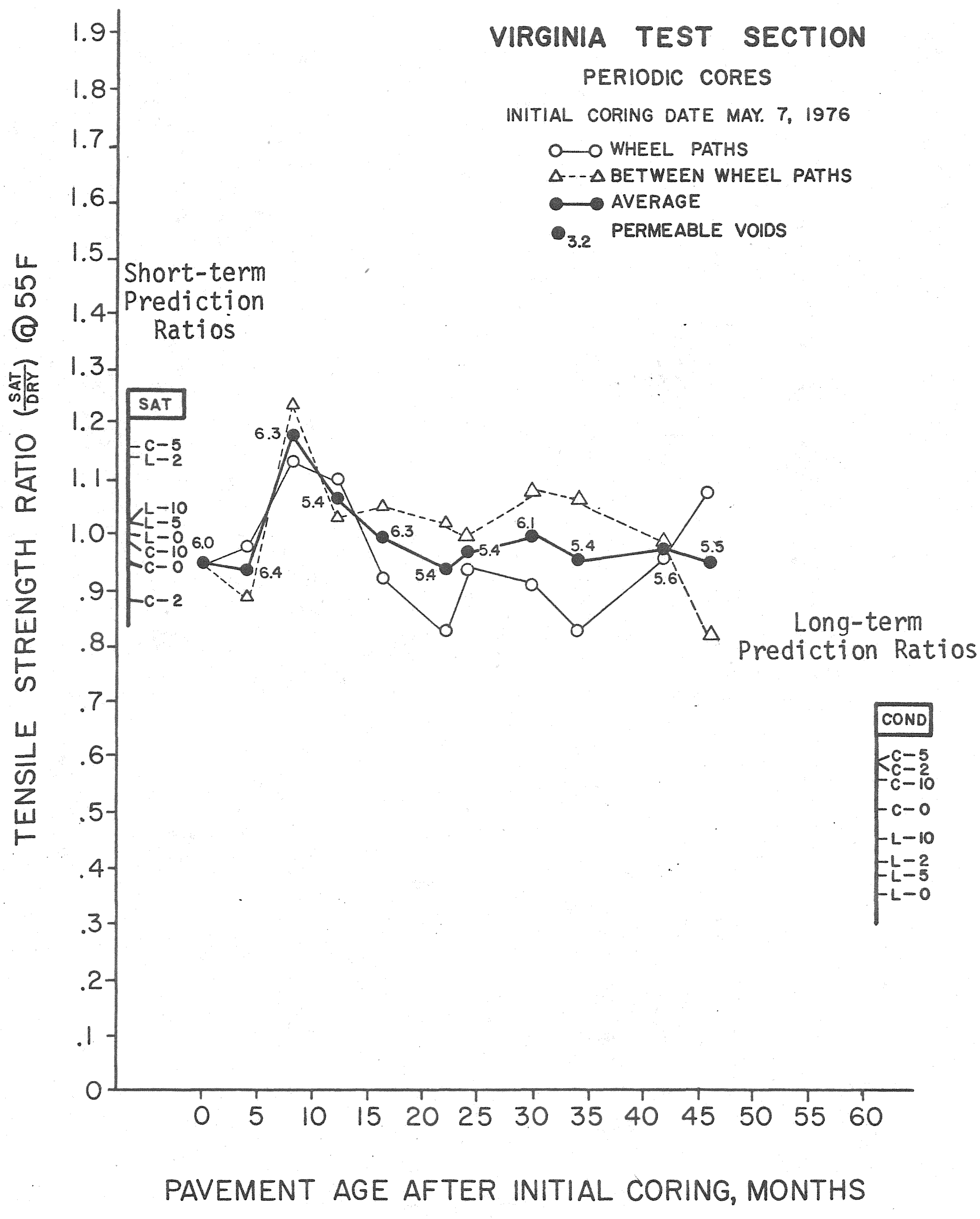

Figure 8. Tensile Strength Ratio of Field Cores vs. Pavement Age and Prediction Ratios for Virginia Test Section

than 1.00. This means that the mechanical properties measured for saturated core and specimen sets are greater than those for dry sets. This is not unusual. None of the mixtures showed stripping after vacuum saturation.

In comparison to the short-term ratios, the long-term ratios are lower and reflect greater differences between the pavement mixtures. For instance, long-term ratios for the Idaho mixture are around 0.80 resulting in a long-term prediction for the Idaho pavement section of 20 percent maximum reduction of cohesive mechanical properties due to moisture damage. In contrast, the long-term ratio for the Georgia mixture, especially with the antistripping additive, is 0, resulting in a long-term prediction of 100 percent reduction of cohesive mechanical properties. In between these two mixtures are the long-term ratios for the mixtures of the other pavement sections. Thus a wide range of long-term moisture damage prediction is established by accelerated conditioning and should form a good basis for the test method evaluation.

Stripping was observed in all mixtures subjected to vacuum saturation plus accelerated conditioning with the exception of the Idaho mixture. Generally the severity of stripping was inversely proportional to the long-term ratios, as expected, but the stripping obscured particular quantitative correlation to a specific ratio magnitude because of the variety of mixtures tested.

Although there are exceptions, the following predictive trends are observed:

1. The ratios predicted using the initial (zero age) pavement cores are somewhat higher than the ratios predicted using laboratory-fabricated specimens. This implies that the paving process accounts for some build-up of interfacial adhesion, aggregate orientation, and other factors which, in the main, impart more moisture resistance in the pavement, at least initially. It is also recognized that laboratory Marshall and Hveem compaction methods do not always give a perfect match to the compacted mixture characteristics of a pavement.

2. The increased storage time of laboratory-fabricated specimens and initial pavement cores appears to impart more moisture resistance, but the effect is generally obscured due to test variability.

3. The laboratory-fabricated specimens containing reduced voids (usually 50 to 75% of the voids of the initial pavement cores and "standard" laboratory specimens) impart more moisture resistance and, hence, generally give higher predictive ratios.

Pavement Moisture Damage Trends

Periodic ratios obtained from the pavement core tests are also plotted in Figures 1 through 8. Although each pavement has its own characteristic plot, the following trends are observed:

1. For most of the pavement test sections the ratios increased over 1.00 as the pavements aged up to and through 12 months. Ratios greater than 1.00 were also observed in the laboratory tests (vacuum saturation), but the pavement effect is greater. Considering the procedure for measurement of pavement moisture damage by the use of ratios and the aging effects of the pavement mixture, it is possible that the asphalt-fines matrix stiffens additionally when water is added through vacuum saturation. It is thought this is because of the molecular action of water penetration into the matrix and also, because the pavement has not yet undergone the offsetting strength decrease effects of stripping and other moisture damage factors.

2. For most of the pavement test sections reaching 4-years of age, the ratios are decreasing and stripping (to various degrees) is being observed. The asphalt-fines matrix stiffening effect is being offset by the stripping. It is also possible that the matrix itself is losing stiffness because both resilient modulus and tensile strength ratios are decreasing below 1.00. In some cases, (e.g. Georgia,) ratios in one year have decreased from 0.95 to 0.40.

3. The amount of stripping observed in the pavement cores drilled at the last reporting of data is as follows:

   Arizona: No significant stripping observed, although the "same" mixture in the next upper pavement layer is stripped severely.

   Colorado: Slight stripping observed.

   FHWA 10: "Dead" appearing sections observed in the cores.

Georgia:	Severe stripping observed throughout some cores beginning to disintegrate. Asphalt additive section is slightly worse than nonadditive section.
Idaho:	A maximum of 10 percent stripping observed; cores appear in good condition.
Montana:	Minor stripping being observed.
Virginia:	Coarse aggregate stripping throughout; insignificant stripping in fine aggregate matrix.

Comparison of Predictions and Pavement Moisture Damage

For the highest long-term predicted ratios (Idaho) and the lowest long-term predicted ratios (Georgia), the probability is that these predictions will closely match the pavement moisture damage measured next year.

The other pavement test section predictions (Arizona, Colorado, FHWA 10, Montana, and Virginia) were in between the highest and lowest, with the long-term ratios ranging from 0.40 to 0.60. So far the ratios of cores from these pavements remain above the predicted ratios, even though stripping is being observed in some cases. (This is assuming that the laboratory-fabricated specimens at zero storage time (L-0) are being used for prediction--the most practical laboratory situation.) Because the healing effects due to desiccation may be offset by the use of the immediate ratios measured at the last core drilling time, the use of this ratio combined with another year of pavement age may provide lower ratios and give closer matches to the predicted ratios for these pavement sections.

Influence of Other Variables

The periodic pavement ratios appear to be lower in the wheel paths than in between the wheel paths, but the trend is not always consistent. The wheel path trend, however, may be better established after the final core tests have been run.

Traffic loading volume (ie., 18-kip single-axle equivalents) may be a factor, but it is not well established to date. There are indications from the data that the pavement ratios reduce at a faster rate with increases of the traffic loading rate.

There are no confirming data to date to accurately separate out climatic factors. It is believed that pavements in warm climates and low elevations will not have as severe moisture damage as those in cold climates and high elevations. The inclusion of a freeze predictive test method could therefore be optional and not used in the milder pavement locations. However, it may be helpful to retain this part of the conditioning in milder pavement locations if heavy traffic is anticipated because it is possible by the introduction of a freeze to shock the aggregate-asphalt interface for high traffic loading simulation and/or to test aggregate soundness.

There has been a slight reduction of permeable voids over the past 4 years that may account for a reduced rate of reduction of pavement ratios, although this factor is not considered significant at present.

Precipitation varies among the pavement locations, and there is some moisture content build-up to about 0.6 percent (average) in the drilled cores (after taking into consideration drilling water when used). The presence of moisture is detected even in the driest location (Arizona). The moisture damage rate seems related more closely to the placement of the pavement. The pavement sections built on high grades may have less moisture available for damage as compared to those built in low areas closer to ground water or run-off sources in equal precipitation locations. If this is true, then the high-grade placement would reduce the rate of moisture damage resulting in several more years of time to reach the predicted long-term damage.

Test Variability

The testing of a set of 4 duplicate specimens or cores was used to obtain an average value and a standard deviation. The coefficient of variation was calculated for these data. The results indicate that the coefficient of variation is lower for the laboratory specimens than for the pavement cores, as expected. Tensile (splitting) strength testing gives a lower coefficient of variation than resilient modulus testing. For the laboratory specimen tests, the coefficients average 0.105 for tensile strength and 0.120 for resilient modulus. For the pavement core tests, the coefficients average 0.145 for tensile strength and 0.170 for resilient modulus.

The foregoing coefficients reflect initial experience with the tensile strength and resilient modulus tests for most of the agencies. The coefficients for laboratory specimen tensile strength tests varied from 0.070 to 0.195 among the highway agencies. More testing experience could narrow the range and could yield a slightly lower average coefficient of about 0.100 for laboratory specimen tensile strength tests.

Test variability may be a factor in the determination of the magnitude of predictive ratios. It is possible that a calculated ratio of 0.50 is not significantly different from a ratio of 0.45 or 0.55 in instances of high test variability. For example, this is observed by the scatter of predicted long-term ratios for different storage times in Figures 1 through 8. The expected trend should show that ratios will increase or remain the same as storage time increases. The test data do not actually show the expected trend, rather they show an "uncertain trend" more-or-less.

Application of the Test Method

Most of the participating highway agencies favor the use of the tensile (splitting) strength test for measurement of moisture damage through the calculation of ratio. The test does not use complicated equipment subject to malfunction and can be performed rapidly. The test load configuration also allows for the splitting of the specimen to observe stripping.

The data (to date) do not support an opinion on which is the better quantitative matching test: tensile strength or resilient modulus. Although ratios calculated from each test are generally similar, there are some differences, perhaps real or perhaps due to test variability. The implication, however, may not be significant.

Several other highway agencies have been experimenting with the test method. Some have used the test method on mixtures that have shown severe stripping in pavements over the last couple of years. Some agencies would prefer to have the freeze portion of accelerated conditioning as an option; some prefer a thermal cycle approach (thermal cycling was originally recommended in the NCHRP Project 4-8(3) (Phase I) study, but at conclusion of the study it was not advocated for most highway agencies because of equipment expense and added conditioning time) or the use of a temperature greater than freezing to achieve a less severe interfacial thermal shock for some milder climate locations. All the agencies appear to agree on the need for several hours of warm-water soaking to finalize the accelerated conditioning.

One agency reported on ratio experimentation with different test temperatures and loading rates for tensile strength testing. They show a relative, practical correlation using the Marshall loading device with flat plates at 2 in./min and at 77F.

Information has also been received that the test method is indeed sensitive to moisture damage variables, having potential for detecting stripping mixtures and for evaluating antistripping additives and lime treatment.

The final pavement moisture damage data, both quantitative and qualitative, should provide a basis for recommendation of acceptable predicted ratios. Expectations are that long-term predicted ratios below 0.50 and above 0.70 would divide the pavement moisture damage performance range of unsatisfactory to satisfactory, respectively. Although the ratio is a simple, linear scale number, it is thought that its corresponding pavement moisture damage performance scale will not be linear. For example, a 50 percent reduction of ratio from 0.70 to 0.35 could result in more than a 50 percent reduction of pavement mixture serviceability life due to moisture damage.

IMPLEMENTATION OF THE TEST METHOD

The NCHRP Project 4-8(3) moisture damage test method applied by the seven highway agencies in this study requires the commitment of adequate time for preparation, testing, and evaluation. The test sequence consists of obtaining aggregate and asphalt to be used for the pavement, determining mixture design, compacting specimens, moisture conditioning, testing, and evaluating. Assuming a mixture is made and cured, 4 days are required for performing the steps. This is about 1 to 1 1/2 days more than the time required to perform the immersion compression test. The following are the main steps:

1. Compacting 9 to 12 standard-type laboratory specimens to the expected permeable voids of the pavement mixture, with expected discard of additional specimens not containing the required permeable voids (calculated after vacuum saturation in step 2).

2. Curing the specimens (overnight is minimum), vacuum saturating two-thirds of the specimens, and placing one-third of them in a freezer.

3. Placing the frozen, saturated specimens in a warm-water bath.

4. Placing all the specimens in the water bath at test temperature (protecting the unsaturated specimens from water intrusion), running the mechanical property tests (tensile strength and/or resilient modulus) at test temperature, calculating the short-term and long-term moisture damage ratios, observing the stripping, and making a decision on the moisture damage susceptibility of the mixture.

These steps require the same testing personnel now employed in the materials laboratories of highway agencies. If several mixtures are being evaluated at the same time, as can be the case with evaluation of antistripping additives and/or aggregate-asphalt types and amounts, the 4 days of performing the test method after mixing will require concentration and preplanning so that the time allocation for the steps will fit into the laboratory working schedule.

Data and observations of this study support the following implementation details:

1. Use only the job aggregate and asphalt (and additives) that will be incorporated into the pavement mixture.

2. Compact specimens to the volume percent of permeable voids that is estimated to occur in the pavement after 1 to 2 years.

3. Perform an accelerated moisture conditioning in addition to vacuum saturation.

4. Evaluate the quantitative moisture damage susceptibility of the mixture using ratios calculated from the mechanical property tests (a minimum acceptable retained tensile strength and/or modulus magnitude is also an additional possibility), evaluate the qualitative results of the extent and character of visual stripping, and evaluate the past experience with the moisture susceptibility of the aggregate and asphalt used. Because of more rapid changes of aggregate and asphalt types now being used, it may be more reliable to focus on the quantitative test results and the stripping observed after tensile splitting.

5. Relate the moisture susceptibility to predicted pavement mixture life. Although a recommendation of acceptable to unacceptable versus ratio will be a result of this study, other factors should supplement the final decision on the acceptance of the mixture. One of these factors is rate of moisture damage. The test method may be better at predicting ultimate magnitude of moisture damage than predicting the time to reach the ultimate damage because of pavement location, climate, traffic, and placement of the pavement mixture layer (pavement design). Thus, a very slow rate of damage may be a factor toward mixture acceptance, whereas a high rate of damage would make the mixture unacceptable--especially for mixtures that have predicted ratios in the middle range (0.50-0.70).

6. Monitor some pavements periodically for purposes of quantifying in-place pavement mixture moisture damage and for refining the relationship between predicted ratios and pavement mixture life (as affected by moisture). The after-desiccation ratios and the use of immediate ratios of pavement cores will be evaluated in this study, and a method will be recommended for pavement moisture damage monitoring.